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THE ERADICATION AND PREVENTION OF BUBONIC PLAGUE.^{1,2}

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Plague is primarily a disease of rodents, and secondarily and accidentally a disease of man.³ Man's safety from the disease lies in the exclusion of the rodent and his parasites. This is the basis of all preventive and eradicated work. If man can live in rodent-free surroundings he need have no fear of plague, because if there be no rodents there can be no rodent parasites, and for all practical purposes the flea may be considered as the common vector of the disease from rodent to rodent and from rodent to man. The eradication of bubonic plague therefore means the eradication of rodents.

In America we have two rodents which are comprehended in this problem, the rat and the ground squirrel, and apparently each plays a very distinct rôle in the propagation and perpetuation of the disease. The rat (*Mus norvegicus*, *M. rattus*, *M. alexandrinus*, and *M. musculus*) is distinctly domestic in its habits, and therefore comes in more or less intimate contact with man. It is also a frequenter of the great highways of the world, traveling long distances in ships and to a limited extent on trains. It is the producer of acute outbreaks, the conduit for the carriage of the virus from its perpetuating reservoir to the body of man. The ground squirrel (*Citellus beechyi*), on the contrary, is not a dweller in human habitations, does not travel except by short migrations, and is an almost negligible factor in the direct transfer of the disease to man. Its great function in the plague scheme is that of a rural reservoir from which from time to time the disease flows over to the suburban rat, thence to his city cousin and thence to man. This condition is not peculiar to America alone, since in China and Thibet the marmota (*Arctomys bobac*) and allied species perform a similar function.

The problem divides itself into two parts, (1) plague eradication and (2) plague prevention.

In the city the fight is directed against the rat and its parasites, and aims to prevent the spread of the disease from them to man. The campaign is conducted along the following lines:

PLAGUE-ERADICATIVE MEASURES.

I. DERATIZATION.^{4,5}

1. Rat slaughter: (a) Poisons—chemical (solid and gaseous), biological; (b) traps—cage, snap; barrel, etc.; (c) shooting, clubbing, and other forms of violence; (d) natural enemies—cats, dogs, ferrets, etc.

¹ Read before the Mississippi Valley Medical Association, Nashville, Tenn., Oct. 17-19, 1911.

² Reprinted from the Lancet-Clinic, Mar. 2, 1912.

³ First, plague in rats,

And then in fleas;

Then plague in man

And quick decease.

No rats, no fleas,

No plague decease.

⁴ For a fuller discussion of this important subject, see "The rat and its relation to the public health," Pub. Health Bull. No. 20. Pub. Health and Mar. Hosp. Serv., Washington, Government Printing Office, 1910.

⁵ Deratization = to rid a certain area of rats.

2. Rat eviction: (a) Destruction rodent habitations; (b) rat-proofing—permanent, temporary, and by elevation.

3. Rat starvation: (a) Proper disposal of edible refuse; (b) rat-proofing of food supplies.

4. Prevention of rat multiplication: (a) All the above; (b) harrying.

II. DEPULIZATION.¹

1. By the destruction of the host.

2. By direct destruction of the flea itself.

(a) Disinfection of rodent habitations and human habitations in which human or rodent cases have been discovered; (b) pulicides—CS₂, kerosene, chlorinated lime, etc.; (c) ordinary domestic cleaning methods; (d) pneumatic suction apparatus; (e) depulization of domestic pets.

III. DELINEATION OF THE INFECTED ZONE.

1. Inspection of: (a) The human dead; (b) the human living; (b¹) contacts to human and rodent cases; (b²) in infected localities.

2. Examination of rats. (a) Macroscopically; (b) bacteriologically.

3. Plague barometers.

IV. PREVENTION OF THE SPREAD OF THE DISEASE.

1. From man: (a) Isolation; (a¹) actual cases; (a²) suspicious cases; (b) disinfection; (b¹) environment—habitation, clothing, etc., cases; (b²) excreta (sputum in pneumonic cases).

2. From rats: (a) Prevention rat migration; (a¹) via natural avenues (sewers, etc.); (a²) via vehicles (trains and ships).

3. By education of the general public.

In the country the measures follow the same general line as in the city and are modified only to meet existing conditions, such as the species of the rodent to be combated, the density of the population, and the different character of the buildings. In America, the only rural animal found to have plague, if we except a single instance of plague infection in the wood rat (*Neotoma fuscipes*), is the ground squirrel (*Citellus beechyi*); therefore attention is focused on the latter species. From the city and the national viewpoint this is plague preventive work; from the country point of view it is plague eradication work. To avoid confusion, it will be classed as a preventive measure, because the work of decitellization is a protective measure of national and international importance.

The work of prevention is directed against the rodent and its parasites lest they import and nourish the seeds of pestilence, later to distribute them to mankind. The plan of campaign is as follows:

PLAGUE PREVENTIVE MEASURES.

I. URBAN.

1. Legal: (a) Rat-proofing ordinances; (b) garbage and refuse-disposal ordinances; (c) sanitary regulation of food storehouses, stables, bakeries, warehouses, etc.; (d) notification and inspection in suspicious illnesses or deaths.

¹ Depulization—to rid a certain area of fleas.

2. Physical: (a) Quarantine against rats—outgoing, incoming; (b) rat proofing of wharves and railroad warehouses; (c) periodical disinfection of ships; (d) laboratory examination of rodents.

II. SUBURBAN.

1. All the foregoing.
2. Creation of ground-squirrel free zones.

III. RURAL.

1. Decitellization: (a) Trapping, hunting, poisoning; (b) laboratory examination to discover new foci of infection and to delineate their boundaries; (c) public education and cooperation.

2. Inspection of: (a) The human dead; (b) suspicious human illnesses.

PLAGUE-ERADICATIVE MEASURES.

I. Deratization.

1. *Rat slaughter*.—It should be borne in mind that when the extermination of a given species is to be attempted reliance can not be placed on any single method. The tremendous fertility of the rat and its ability to survive in the most unfavorable environment makes it necessary that the campaign of deratization be approached simultaneously along every avenue of murine existence.

(a) Poisons: When skillfully prepared and intelligently distributed, poisons kill off a certain percentage of the rodent population. This measure has proven very efficacious in the hands of the United States Public Health and Marine-Hospital Service at San Francisco. The biological products depend largely upon the bacillus *Typhi murium* of Loeffler, and aim at the production of epizootics which are not harmful to man. Unfortunately, this has not proven a very certain or satisfactory means of killing rats, and moreover this organism is pathogenic for man.

The chemical poisons, such as arsenious acid and phosphorus, on account of their cheapness and certainty of action, have given very good results. Of the two, phosphorus is perhaps preferable, owing to the fact that rats seem to take it better. Barytes (crude barium carbonate) will kill rats, but on account of its metallic taste is not readily taken by them. Strychnine is a valuable agent, but is expensive, and because it is often distributed on the small grains is less convenient to handle and is more dangerous to children and domestic animals. When used in grain it is more apt to be taken by birds, whose death will usually raise a storm of protest from the lover of the song birds. When used to kill rats, a favorite method of distribution is to split open a prune and place the toxic agent in the center. Powdered squills is sometimes used, and is toxic for rats.

Whatever the agent employed, it should be distributed in as attractive a menstruum as possible. In the case of arsenious acid, it should be incorporated in a base of some fatty material, such as lard sweetened with sugar, flavored with oil of anise or musk, and colored a light pink. Phosphorus is most safely incorporated in glucose. Its liability to spontaneous combustion should be borne in mind. It is well to change the base frequently, alternating between cheese, lard, mutton fat, corn meal, and ground fish, such as salmon. The mass should be of such consistency as to permit its spreading easily on slices of bread,

which are afterwards cut into small cubes about three-eighths of an inch square.

In distributing poisons care must be observed lest they be taken by children or domestic animals. An accurate record should be kept of every place in which poisons have been put, and frequent inspections should be made to determine the results obtained. When it is decided to cease poisoning in a certain neighborhood, it is wise to collect any remaining portions of the toxic morsels lest they be taken in some unexpected way in the future.

(b) *Traps*.—Trapping rats not only assists in decreasing their numbers, but also enables us to detect murine epizootic plague by laboratory methods in time to prevent its becoming human epidemic plague. Their long association with man has given rats a wary cunning which is remarkable, therefore trapping is an operation requiring great ingenuity and patience, as well as a thorough knowledge of their habits. The large wire cage has the advantage of catching the animals alive, and very frequently more than one at a time. In certain situations, however, the snap, guillotine or dead fall traps seem to give better results. In placing traps the environment should be changed as little as possible and advantage taken of the usual rodent runways. It should be borne in mind that in daylight the rat's eyesight is somewhat defective, producing an agoraphobia, but by depending on their vibrissæ they can run along a side wall with celerity and ease. Traps therefore should not be placed in large open places, but in a narrow runway or beside a wall. Great care should be exercised in choosing baits; they should be changed frequently, and should be some delicate, odorous morsel which the rat is not in the habit of getting. Traps should be visited, emptied, and reset every other day.

Barrel traps are useful in warehouses where rats exist in great numbers. They consist of a cask half full of water and having a lid which will tilt and precipitate the animal into the water beneath. A large piece of rancid cheese attached to the middle of the lid serves to attract the rat. A board, one end of which rests on the floor and the other on the chimes of the barrel, insures the approach of the rat from the proper side.

Captured rats should be labeled to show where, when, and by whom secured. They should be treated with some efficient pulicide for the protection of those handling them, and if they are to be examined they should be transported to the laboratory in flea-proof containers.

In cold-storage warehouses rats have been successfully eradicated by suspending a bait between two heavily charged overhead electric wires from which the insulation has been removed for a short distance. The hungry rodent, crawling over the wires, shunts the current through its body and falls unconscious into a tub of water in which it is drowned.

There has been patented a system of tunnels and traps to be installed into ships at the time of construction. It includes registering devices to indicate the number of rats in the trap, and after a sufficient number have been captured they are driven into a pit where they are killed with gas and then removed. The system was installed into a hotel at Coronado Beach, Cal., and seems to promise much.

(c) *Shooting, clubbing, and other forms of violence*.—In situations in which rats are unusually abundant—e. g., abattoirs, stockyards, food

markets, and provision warehouses—large numbers may be killed by shooting with a .22-caliber rifle or by “rat drives,” the animals being forced into some confined place and killed with clubs or large knives. This measure is rarely of any great value.

(d) *Natural enemies*—cats, dogs, ferrets, etc.—As natural enemies of the rat, dogs, cats, weasels, ferrets, snakes, and owls take first place. In the open, owls are very successful rat catchers, and in certain latitudes nonpoisonous snakes have proven effective in ridding warehouses and stores of rats. Dogs, cats, weasels, and ferrets are very useful in decreasing the rodent population, but on account of their susceptibility to pest it is deemed wise to limit their activities to normal times, lest they carry the disease from their prey to man.

2. *Rat eviction*.—The homeless rat is exposed to the attacks of its predatory enemies; it has little chance to multiply, and it must constantly be on the lookout for new sources of food supply. Rat eviction is of value in another important way—it removes the rat from the home of man. If this eviction is permanent, the danger from plague has been removed.

(a) *The destruction of rodent habitations*.—This is important not only in that it evicts the rat but it also affords an opportunity to kill the fleas which are generally found in the rat nests. Furthermore, the tearing up of old sidewalks and planked-over back yards is the first step toward their replacement with concrete or similar rat-proof material. When the rat warren is in piles of rubbish, its destruction is of value as a clean-up measure quite as much as an antipest measure.

(b) *Rat proofing, permanent, temporary, and by elevation*.—Of all the antiplague measures yet devised by man the one which is of greatest and most lasting value is permanent rat proofing. A rat-proof city shall not fall from plague. Rat proofing acts not only as a means of plague eradication—it is the fortification against its subsequent attacks. The subject is therefore of great importance to the general public both from the sanitary and commercial viewpoints. Rat proofing serves the purpose of protecting the inmates of the building from plague and of excluding the rat from its food supply and habitation. It is the insulation against the rat which is to be applied as a general measure in all plague-infectible localities, especially those which have suffered from predations of the disease. Permanent rat proofing costs money, but it must be regarded as plague insurance both from the commercial and the humanitarian aspect.

Concrete has been found to be the best rat-proofing material for general use. It is fairly cheap, and its permanency is unquestioned. Concrete foundations, basements, and floorings should be installed in houses, stables, warehouses, and markets where food products of any sort are stored. Particular attention should be paid to buildings or places where domestic creatures are fed. This applies particularly to chicken yards, which, on account of the amount of uneaten food usually scattered about, are overrun with rats. If the yard be paved with concrete and provided with rat-proof wire screening, the chicken yard will be less of a menace.

Galvanized iron has been used as a temporary makeshift, but is not wholly satisfactory. If used, it should be regarded as a temporary measure only.

If buildings are elevated 18 inches above the surface of the ground, and free access to the space beneath allowed for ingress and

egress of the natural enemies of the rat, rat-proofing by elevation is secured. This measure is of value in treating small frame structures in which other methods of rat-proofing are contraindicated by reason of their cost. It is a temporary measure.

Whatever method of rat-proofing is used, it should be remembered that rats will enter a building through doors and windows, hence these should be carefully guarded against rodents. Rats (particularly the *M. alexandrinus*, which, fortunately, is not plentiful in the United States) will also enter buildings by way of the roof, hence this avenue of ingress should be closed against them.

3. *Rat starvation*.—It is useless to expect the rat to take poisons or to be attracted by the baits in traps as long as there is an abundance of food which can be easily obtained. Therefore rat starvation is an eradivative and preventive measure of great importance. Furthermore, rats, like every other living creature, will not stay where there is an inadequate food supply. This probably accounts for the various migrations of rats described in so many different countries.

(a) *Proper disposal of edible refuse*.—The days when the rat served as the public unpaid scavenger are passing. The health departments of the large cities now require the disposal of garbage in water-tight well-covered metal containers, and the careful collection of such material in covered wagons and its final destruction by incineration or reduction. This is an important sanitary measure, not only on account of its effect on rats, but also because of its effect in doing away with a breeding place for flies. Equal care must be taken in the disposal of wastes from vegetable, fruit, and meat markets. Other waste products, such as stable manure, which furnishes both bed and board for the rat, should be stored in metal-lined boxes, which are frequently emptied and the contents incinerated or shipped to the country for use as fertilizer.

(b) *Rat-proofing of food supplies*.—Groceries, meat, fish, vegetables, and fruit markets, restaurants, bakeries and all places where food is prepared or sold for human consumption, are great dispensers of rat pabulum. The barriers to be erected against rats will vary according to the nature of the premises. Markets and other places where foods are constantly being shifted about should be well protected against rats by the use of heavy wire screening with not over one-half inch mesh. Elevators and other places for the storage of grains or hay should be rat-proofed and cats installed to keep them rat free.

(4) *Prevention of rat multiplication*.—The starved and evicted rat, harried from place to place by the incessant warfare which is being waged against him, "remote, unfriended, melancholy," has small chance of multiplying. The Japanese observers have argued that as the rat population diminishes, the breeding rate among the survivors increases because of the relative increase in the food supply and the number of rat-harboring places. If deratization has been attempted by a simultaneous, systematic attack on the rats' home and source of aliment, conditions unfavorable to breeding are brought about. It is probably impossible to absolutely exterminate the species in a given city, but this is not absolutely necessary to the eradication of plague. If the rat population is kept within fairly few limits and is not congested, rat plague will die out from purely natural causes. Or, should it be introduced into a sparse and scattered rodent community, the disease will soon exhaust the material necessary for its perpetuation.

II. Depulization.

The flea is the intermediate agent for the transference of the germs of plague between the body of the moribund rat and that of another rat or of man. If we rid ourselves of the mammalian host on which this insect lives, we need have little concern about the rat flea. In time of epizootic or epidemic plague it is necessary, however, that every factor in the transmission of the disease be taken into consideration.

(a) *Rodents' habitations*.—During the destruction of rodent habitations, large numbers of fleas are met with in the rat nests, which are most commonly found beneath wooden floors and lumber piles and in accumulations of rubbish and manure. Some of these fleas may be pest infected, certainly all are capable of becoming plague-germ vehicles; therefore their destruction is necessary. It is even more important that fleas be killed in human habitations in which human or rodent cases have been discovered.

The flea is covered with a heavy chitinous armor, and breathes through a row of small openings or spiracles situated laterally along the abdomen. This is the flea's vulnerable point, hence the attack on this insect is made through its respiratory apparatus. Fumigation with sulphur dioxide is probably as good a method as we possess. Formaldehyde is valueless as an insecticide. The sprinkling of fresh chlorinated lime in rat nests will kill the resident fleas at all stages of their development. Liberal applications of crude cresylic acid also seem effective. An emulsion of water and kerosene, distributed in a fine spray is a fairly efficient pulicide, especially when mixed with banana oil and wood alcohol.

(b) *Ordinary domestic cleaning methods*.—It is desirable, both for the comfort and safety of persons living in the infected zone, that their houses be kept flea free. The frequent beating of rugs and carpets in the bright sunshine and the thorough removal and incineration of dust will kill many fleas and destroy their eggs. The treatment of floors with a kerosene emulsion or similar pulicide will kill the eggs, larvæ, and nymphs in the floor cracks.

(c) *Pneumatic suction apparatus*.—Many of the pneumatic cleaning devices now on the market will completely remove the dust from carpets, rugs, hangings, and furniture. Inasmuch as it is in dust that flea eggs are found, its removal and destruction will rid a building of fleas. This measure is particularly important in places of public congregation, theaters, churches, and schools, which are usually not well cleaned by the ordinary methods.

(d) *Depulization of domestic pets*.—There are many houses in which fleas persist in spite of careful cleaning and the liberal application of pulicides, and it is not uncommon to find that a cat or dog is the flea importer. The remedy is obvious, either to exclude such animals from the house or to keep them flea-free by frequent baths.

III. Delineation of Infected Zone.

It is essential to the successful conduct of an antiplague campaign that accurate knowledge be secured as to the extent and distribution of the infection, both in the human and rodent populations.

1. *Inspection of (a) the human dead*.—When plague makes its appearance in a community, ignorance prompts its concealment.

Furthermore, its diagnosis will puzzle anyone who has not seen the disease or who is not expecting to discover a case. Then, too, there is always the fear of injury to commercial interests, a psychological phenomenon which would eradicate disease by proclamations and denials. The inspection of the human deaths, particularly among Asiatics, is therefore an important measure. It is usually accomplished by refusing to grant a burial permit until the body has been viewed by an authorized inspector. Necropsies should be held in doubtful cases.

Inspection of (b) the human living.—It is equally important that living human contacts to both (a¹) human and (b¹) rodent cases be kept under surveillance until this period of incubation is past. This is not an eradicated measure in the strictest sense of the word, because, in the absence of ectoparasites man is an almost negligible factor in the spread of the disease, but it is of value in that it affords opportunity for the early administration of prophylactic or curative treatment. For the same reason it is well to keep all persons who live in heavily infected districts under fairly close observation.

(2) *Examination of rats.*—As has been noted above, the discovery of the infection among rodents is of value, in that it affords an index of the extent and distribution of the epizootic, so that immediate steps may be taken to prevent the disease being transferred to man. It is a measure which should be a routine practice in all large seaports lest the disease should be imported and smoulder in the rodent population, its arrival being discovered only after human beings have been attacked. It is not difficult nor expensive, and will pay for itself in the security from plague which it affords, at the same time preventing the commercial losses which are attendant on the announcement of the appearance of the disease among human beings.

The rats to be examined are freed of their ectoparasites by immersion in some efficient pulicide and tacked to shingles. After a record has been made of the place and date of capture, the skin is reflected from the ventral surface and the occurrence of subcutaneous injection and glandular enlargements noted. The peritoneal and thoracic cavities are then opened and the condition of their contents observed. The gross pathological lesions of plague are so characteristic that the layman of average intelligence readily learns to recognize them. In the plague laboratory of the United States Public Health and Marine-Hospital Service at San Francisco all rats having suspicious lesions are laid aside by the attendants engaged in performing rodent necropsies, and are later gone over carefully by the bacteriologist, who verifies or disproves the diagnosis by the usual microscopical and bacteriological technique.

3. *Plague barometers.*—Another method of outlining the plague zone has been by the use of the guinea pig as a plague barometer. Taking advantage of the natives' love of household pets and the propensity of the flea to get on the guinea pig, the Indian Plague Commission placed two or three guinea pigs in each house in the infected zone. Householders were instructed to notify the health authorities as soon as a pig sickened or died. The sick or dead pig was then examined, and if found to be plague-infected the premises from which it was taken were subjected to the usual antiplague disinfection and other measures.

IV. Prevention of the Spread of the Disease.

Once having delineated the infected zone, it is the endeavor of the sanitarian to prevent its enlargement and to protect those living in the zone itself.

1. *From man*.—As has been previously pointed out, in the absence of ectoparasites, man plays a small rôle in the spread of plague.

(a) Isolation affords a way to separate (1) actual and (2) suspicious cases from their parasites, and is a wise measure. It also reacts to the benefit of the patients themselves, as it insures their treatment by persons who have acquired skill in the treatment of plague.

(b) Disinfection of the (1) environment from which the patient has been removed is important, not only because of the destruction of the insects and bacteria, but also because of the effect it has on the general public. The disinfection of the (2) excreta is indicated in the pneumonic cases in which the sputum is loaded with the plague bacillus. The stools and urine are not known to be infectious.

2. *From rats*.—The prevention of the spread of the disease from rats has been fully discussed under the headings "Deratization" and "Depulization," but it may be noted that the prevention of rat migration has an effect in preventing the scattering of the seeds of pestilence. When rats are cut off from their homes and food supplies, they naturally will migrate through sewers and other subterranean passages, but occasionally over land. All openings into sewers which could be used as rat runways should be closed or rendered impervious to rats. The idea should be not to keep the rat out of the sewer, but to keep him *in* the sewer, where he is harmless to man. The prevention of rat migration by trains and ships will be discussed elsewhere in this paper.

3. *By the education of the general public*.—It may be taken as axiomatic that no public-health campaign can succeed in its fullest extent without the intelligent cooperation of the general public. It is not to be expected that the public will lend their aid in the suppression of a disease about which they know little and of whose existence in their community they are usually very doubtful. There is only one way to meet this phase of the problem, and that is by the education of the public as to what plague is, how it is carried, and what the public's duties are in its prevention and eradication. The exact truth as to the situation should be told, and if the lesson is repeated often enough and patiently enough surprisingly good results will be obtained. Every walk of life, every stratum of society, should receive this instruction; the business interests, the women's clubs, the churches, the schools, the social organizations must be included in this campaign of publicity. Every householder unconsciously becomes a sanitary inspector; every housewife, as she puts the lid carefully on the garbage can, becomes an agent of the department of public health; every schoolboy reads into the familiar lines about the cat and the mat and the rat the great lesson of plague. Truly, publicity is the handmaid of sanitary science, particularly with regard to bubonic plague.

PLAGUE PREVENTIVE MEASURES.

Urban.

The foregoing outline of the eradicated measures to be used against plague naturally suggests those to be put in force for its prevention. Until efficient barriers have been erected against the

rat, there is no maritime commercial center in the world which can be regarded as free from the danger of pest invasion.

1. *Legal.*—In both the city and the country laws are necessary to enforce the destruction of rodents and to bring about their isolation from the home of man. This should be, first, a matter of State law, declaring the presence of rodents in and about places of human occupation to be a menace to health; and, secondly, requiring that property holders make a reasonable effort to prevent the residence of rodents on their premises. The law should also provide a penalty for its infraction. The States of California and Idaho have enacted such laws. Cities and counties may accomplish much the same result by ordinances, and may make further provisions as their needs require.

(a) *Rat-proofing ordinances.*—Rat-proofing ordinances should be specific and should state the character of the rat proofing which shall be used in the different classes of buildings. Boards of health should be charged with the enforcement of such ordinances and should be given power to condemn rat harbors, or to order their rat proofing under penalty of condemnation after a reasonable time has been given in which to complete their rat proofing. Such measures, if enforced, guarantee "building the rat out of existence," and, aside from their value as a plague prophylactic, prevent much destruction by rats, and in some instances by fire.

(b) *Garbage and refuse disposal ordinances.*—Ordinances relative to the manner of disposal of wastes, particularly those which furnish rat pabulum, should be enacted and enforced. The water-tight metal garbage can with close-fitting lid should be the standard, and the ordinance should carry a penalty for the disposal of garbage in any other receptacle and should state the degree of cleanliness in which the can is to be maintained. The collection in sanitary vehicles and final disposal of the collected materials should also be regulated by ordinances enforced by the board of health. Wastes from food markets, both wholesale and retail, require similar careful regulation.

(c) *Sanitary regulations of food storehouses, stables, bakeries, warehouses, etc.*—Unregulated places where food is stored or prepared furnish an ideal environment for rat habitation and propagation, unless great care is taken. Ordinances requiring that they be maintained in a cleanly, rat-proof and rat-free condition react not only to the prevention of plague, but also to the general health of the community. It was found that the antiplague work done by Surg. Rupert Blue, of the United States Public Health and Marine-Hospital Service in San Francisco, not only eradicated plague but also reduced very greatly the incidence of infectious diseases in that city. It is also interesting to note in passing that the sanitation of the stables in that city not only reduced the number of rats and flies very greatly, but also caused a great falling off in the diseases of horses.

(d) *Notification and inspection of suspicious illnesses or deaths.*—In cities which have had plague, or which are in steamship communication with ports in which plague exists or has existed, physicians should be required to report to the health department all cases which are actually plague or suspected of so being. Such ordinances, if occasionally brought to the practitioner's notice, keep before his mind the possibility of the occurrence of plague in his practice.

2. *Physical*.—(a) *Quarantine against rats, incoming, outgoing*.—Since the prime object of plague preventive work is the reduction of the rodent population, it is necessary that the importation of rats be prevented. It is also important that the exportation of rats from infected ports be prevented. The best way to accomplish this is by periodic fumigation of ships, the great disseminators of plague. "Where ships go, there plague will go." Therefore vessels should be fumigated just prior to sailing from infected ports, lest they carry plague rats as an unwelcome addition to their cargo. Ships not so fumigated should be fumigated on arrival. If the nations of the world would cooperate to secure the periodic fumigation of ships to kill rats, and would undertake the surveillance of outgoing passenger and freight traffic at infected ports, ship-borne plague would become a thing of the past. Probably the best agent for fumigation to kill rats is sulphur dioxide. To be effective, every compartment in the entire ship must be treated simultaneously with gas of a minimum strength of 3 per cent, five hours' exposure being given. If ships are fumigated prior to taking cargo, care must be observed lest they again become rat infested, the rodents being carried into the holds in freight, or by climbing on board by way of the mooring tackle. Freight should be inspected prior to loading, and cargo originating in rat-infested surroundings should not be accepted for shipment. Vessels should be sheered off from the dock, and all lines and timbers over which rats could pass to the ship should be guarded by large metal funnels securely lashed on. (b) As an aid to the prevention of the shipment of rodents in freight, wharves and warehouses should be rendered rat proof and maintained rat free.

Rural.

In the foregoing we have considered the prevention and eradication of epizootic rat plague. Let us now take up the question of enzootic plague as it applies to the ground squirrel. The function of this species as a perpetuating reservoir for plague had already been suspected for some time, but it was not until the autumn of 1908 that plague-infected ground squirrels were found in nature. This discovery was made in Contra Costa County, Cal., and it was immediately seen that a new plague focus had been uncovered and that it must be rapidly delineated. This work has been actively prosecuted since the spring of 1909 by the United States Public Health and Marine-Hospital Service, and the infection has been found in the ground squirrels (*Citellus beechyi*) of 11 counties, or about one-seventh of the total area of California. It should be noted that the operations of 1911 have demonstrated the infection in only seven of the originally infected counties, the eradication measures apparently reducing the area of infection. Some conception of the magnitude of these operations may be grasped from the fact that in the 26 months ending June 30, 1911, 252,743 squirrels have been secured, of which 250,666 have been examined for plague infection, and out of this number 483 have been found to have the disease. For the most part, plague exists in chronic form in the ground squirrel, but occasionally small areas are found, the squirrels from which present the lesions of acute plague. Experiments have proven that the squirrel flea (*Ceratophyllus acutus*) will transmit plague to

rats, and that the rat flea (*Ceratophyllus fasciatus*) will carry the disease to squirrels. The chronicity of the disease in squirrels insures its perpetuation without the extermination of the host species. The ability of the squirrel flea to transmit the disease to rats permits the spread of the disease from the rural squirrel to the city man through the chain of suburban and urban rats. Furthermore, the gradually enlarging boundaries of the disease among ground squirrels forecasts its continued spread throughout the species. This is the most serious aspect of the problem, because the citellus is a widely distributed species.

Beginning with Oregon and Washington on the west, the life zone of the *Citellus columbianus* extends eastward across Idaho, Montana, North Dakota, and South Dakota to mid-Minnesota. Northern California is occupied by the *Citellus douglassi*, while the central and southern portions of that State are inhabited by the *Citellus beechyi*. This species occupies the lower mountain passes and is thus in contact with the *Citellus grammurus*, whose life zone extends from the southern border of the distribution of the *Citellus columbianus* on the north to the Rio Grande on the south. On the southern half of the eastern border of California the *Citellus grammurus* is bounded by the *Citellus fisheri*, while its eastern limitation is the *Citellus franklini*, which has been found as far east as mid-Michigan. It is also probable that the *C. franklini* is distributed to a certain extent in the Eastern States, as colonies are known to exist in western Massachusetts. The *C. fisheri* is distributed in a narrow strip along the lower half of the eastern border of California.

From the foregoing it may be deduced that the spread of the disease in the ground squirrel might some day cover the Nation with a pall of plague reaching from the Pacific to the Alleghenies. Fortunately, the work of eradicating the focus has been begun in time and is being relentlessly prosecuted.

1 *Decitellization*.¹—The lines of attack are very much the same as in the combat against the rat, due allowance being made for the difference in habits and environment of the two species.

(a) *Trapping, hunting, and poisoning*.—Many ground squirrels may be caught in spring traps or snares. These should be marked by a rod about 3 feet long and bearing a small red flag on the top. This prevents loss of traps. Traps should be visited every few hours, lest the catch be stolen by birds or small mammals. Snares should be made of brass wire. They are useful in taking samples for laboratory work, because the squirrel is not injured in any way. It should be borne in mind that squirrels do not live long when caught in a trap and exposed to the sun.

The shotgun is the best weapon for hunting squirrels either for laboratory examination or eradication. Twelve or sixteen gauge guns and number eight shot seem to give best results.

Strychnine is a valuable agent in poisoning squirrels, but has the disadvantage of being taken by other animals and by birds. Carbon bisulphide is very useful and kills them readily, if put in the squirrel burrows properly. It also has the advantage of killing the fleas in the burrows at the same time.

¹ Decitellization—to rid a given area of ground squirrels.

(b) All squirrels secured, whether shot, trapped, poisoned, or found dead, should be subjected to laboratory examination. The technique is the same as for rats.

(c) *Public education and cooperation.*—What has been said of the value of public plague education in cities applies with equal force to the country. The farmer must be taught how to kill ground squirrels and he must be encouraged to rid his premises of them. He is usually very glad to do this, on account of the destructiveness of the citellus to crops, and it is not hard to secure his cooperation.

2. *Inspection of (a) the human dead and (b) suspicious human illnesses.*—If man would let the squirrel severely alone there would be little danger of contracting plague from it direct, but, unfortunately, this is not always done. In the case of hunters and persons engaged in handling rats and squirrels they may be Haffkinized, but thus far the general public has not taken very kindly to this method of protection, and cases from ground squirrels are so rare in proportion to the number of people handling them that this means of prophylaxis can not be urged. However, one or two cases of plague occur each year from contact with squirrels; therefore it is wise to insist on an inspection of the dead in the infected area during the period of greatest epizootic plague prevalence. An inspector should always be available for the inspection of cases of human illness which are thought to resemble plague.

Suburban.

1. *The creation of ground squirrel free zones.*—It has been shown above that plague is transferred from the country ground squirrel to the city rat by way of the suburban rat, and that the transfer in each case takes place in the area in which their life zones overlap. If this area be decitellized, then the danger of the transference of the disease from rural ground squirrel to suburban rat is obviated. This is sound in both theory and in practice, for it has been found in California, where a great squirrel free zone has been thrown about the Bay cities, that rat plague does not exist at present in them, despite the fact that it exists in the country squirrels thereabouts. This zone is kept free of squirrels by a patrol of hunters and trappers and forms an efficient barrier against the introduction of plague from the rural focus.